An approach for evaluating the significance of potential fault sources on seismic hazard: *A case study using the August 2011 Mineral, Virginia, aftershock-delineated fault source*
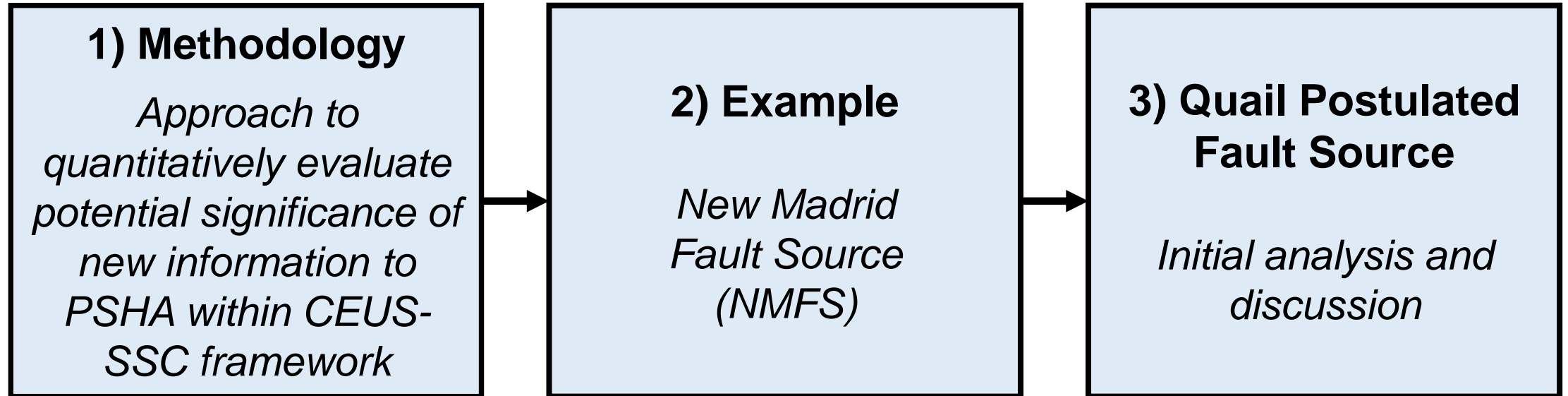
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2016 Natural Phenomena Hazards Meeting and Training Session, October 19, 2016

Introduction

- When does new information trigger need to update the CEUS-SSC (or other) seismic source models?

- Need for traceable methods, vs. expert judgement, for model updates

- Approach: Evaluate new information from the aftershock-delineated fault source from the August 2011 Mineral, VA, earthquake (termed the Quail fault) and determine if it affects the PSHA and use of the CEUS-SSC model?

Presentation Outline

1) Methodology

Approach to quantitatively evaluate potential significance of new information to PSHA within CEUS-SSC framework

2) Example

New Madrid Fault Source (NMFS)

3) Quail Postulated Fault Source

Initial analysis and discussion

Methodology: Performing a Sensitivity Analysis by adding a Postulated Fault Source to the CEUS-SSC

1. Determine hazard at site using CEUS-SSC and EPRI GMM

2. Compare the rates from the CEUS-SSC background seismicity sources with the postulated recurrence rates for the postulated fault source

3. Determine hazard at site from the postulated fault source

4. Compare the hazard at site with and without adding the postulated fault source at 10^{-4} and 10^{-5} annual frequencies of exceedance

5. Make final evaluation as to whether adding the postulated fault source significantly impacts the hazard at site

Postulated RLME Example : NMFS

- Assume NMFS has not been included as an RLME in CEUS-SSC model

- Does adding NMFS RLME significantly impact the 1 Hz hazard at Toledo, OH?

320 km

500 km

km

0

500

CEUS-SSC Mmax Zones & RLMEs w/in 500 km

Earthquakes ≥ magnitude
2.0 – red, 3.0 – green, 4.0 – blue,
5.0 – orange, 6.0 – purple, 7.0 – black
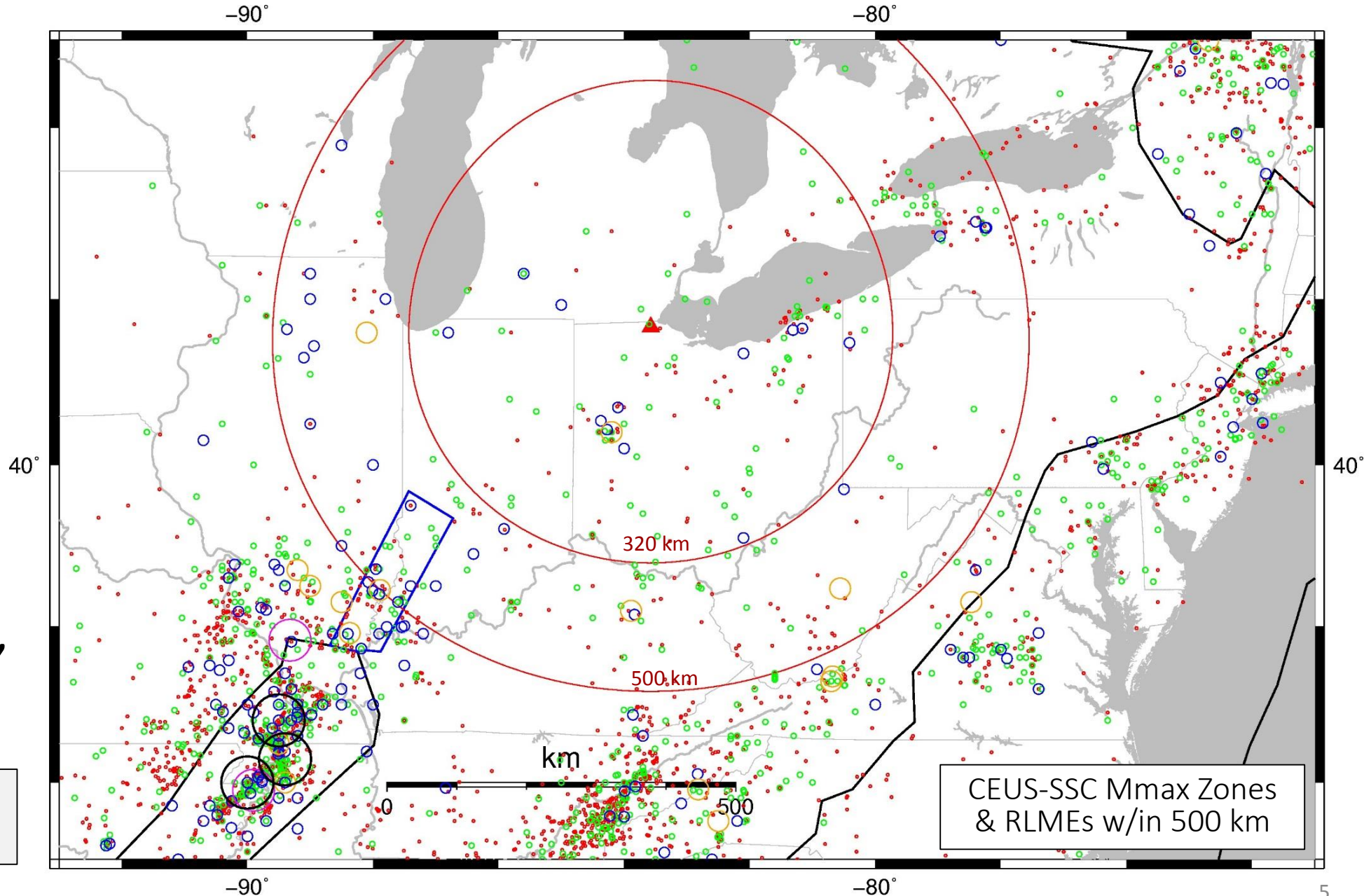
Postulated RLME: NMFS
NMN: New Madrid North
NMS: New Madrid South
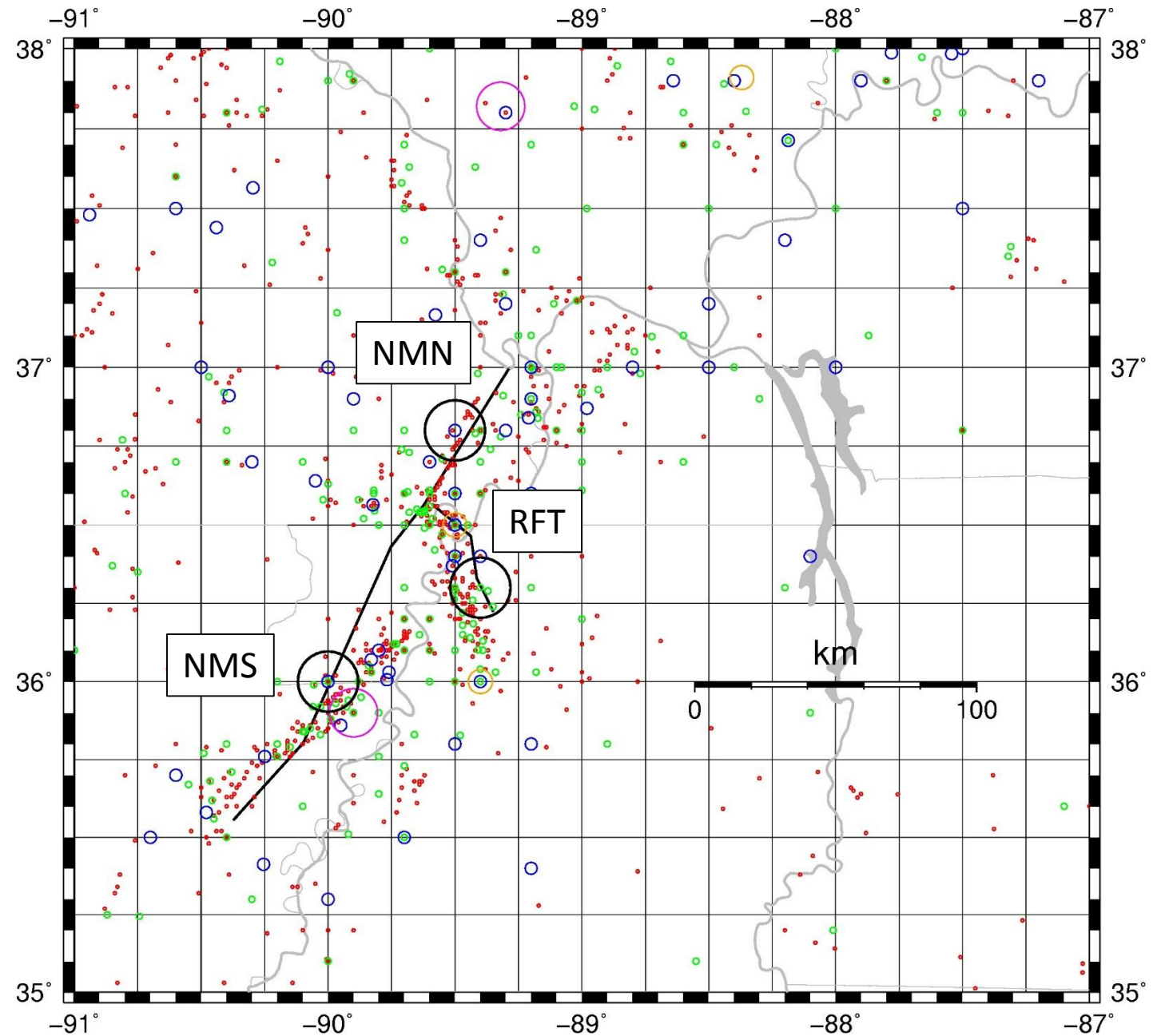RFT: Reelfoot Thrust

Earthquakes ≥
magnitude
2.0 – red
3.0 – green
4.0 – blue
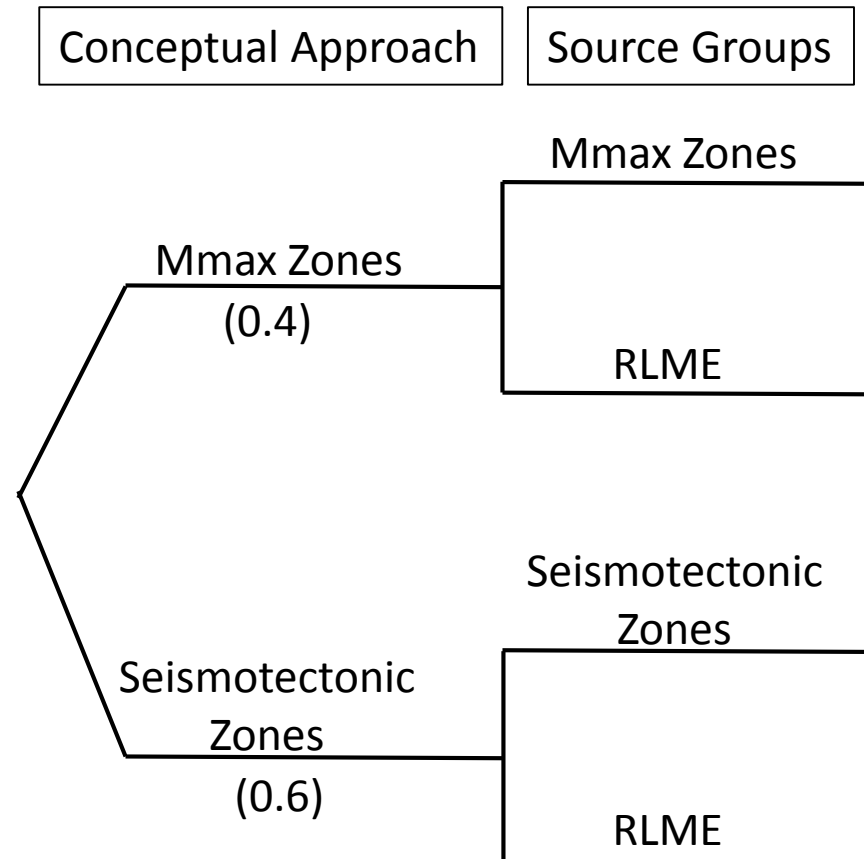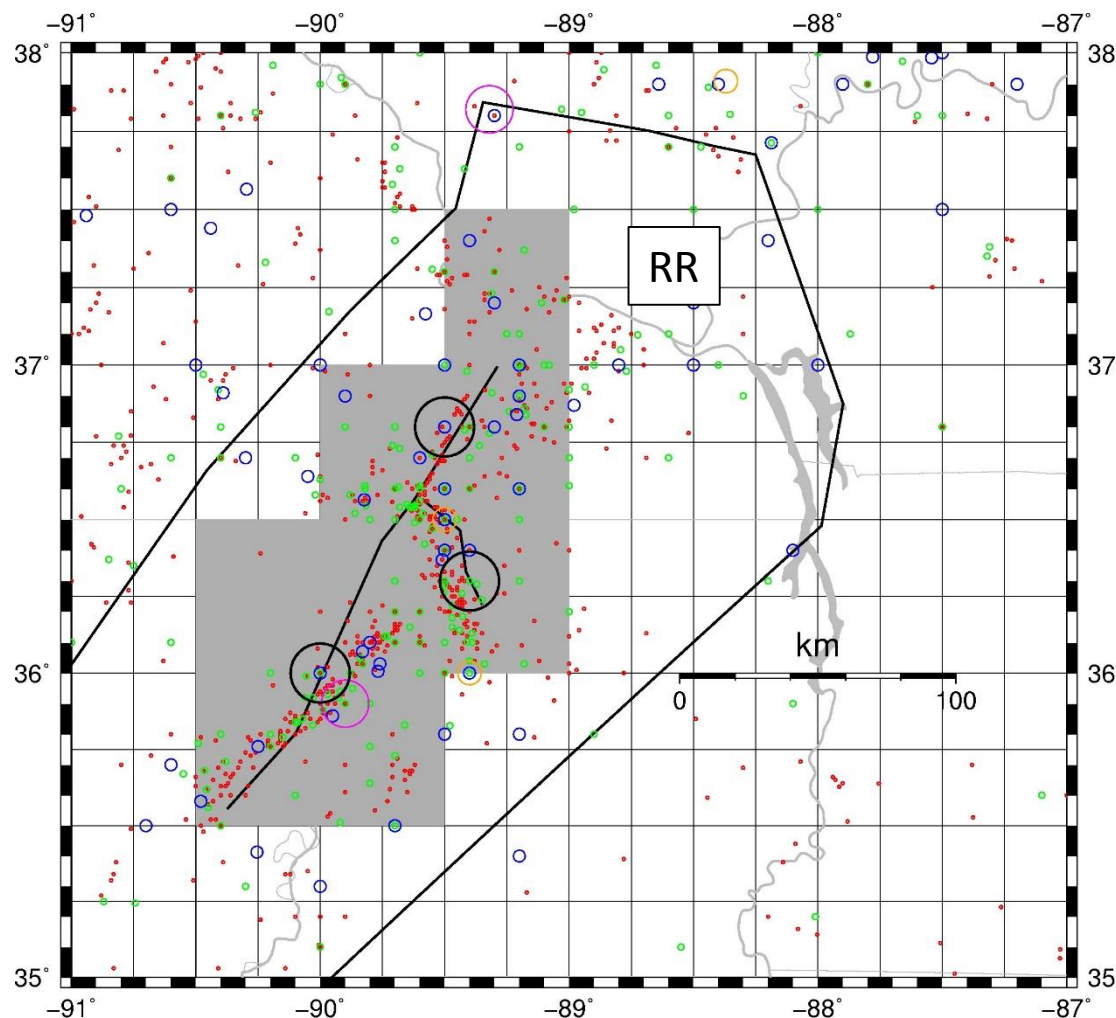5.0 – orange
6.0 – purple
7.0 – black

NMN

RFT

NMS

km

0   100

Overall CEUS-SSC Seismic Source Logic Tree

Conceptual Approach | Source Groups

Mmax Zones
(0.4)

Mmax Zones

RLME

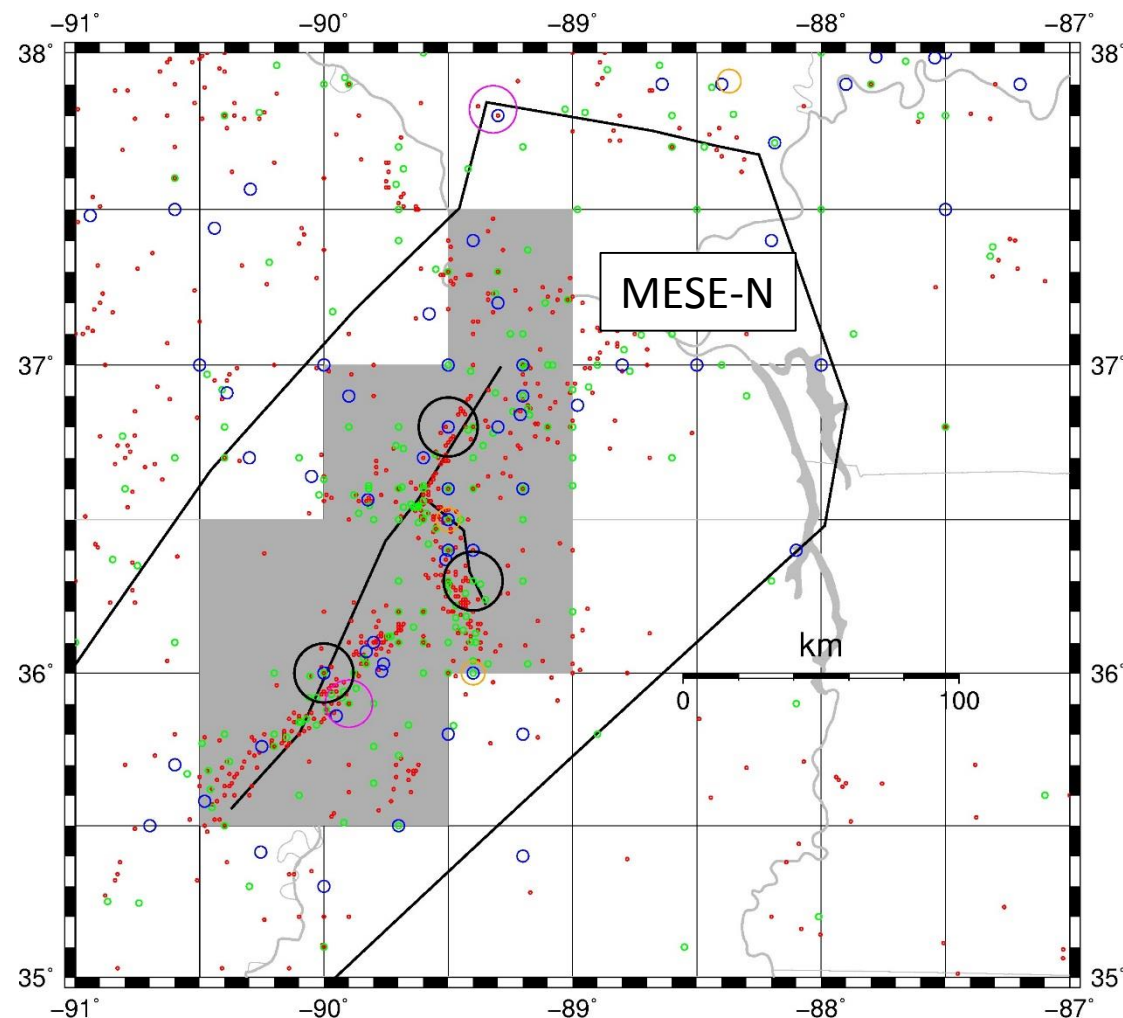Seismotectonic
Zones
(0.6)

Seismotectonic
Zones

RLME

Seismotectonic Zones:
RR and RR-RCG

8 realizations x
3 cases (case A, B, E)
= **24 rates for each source**

Mmax Zones:
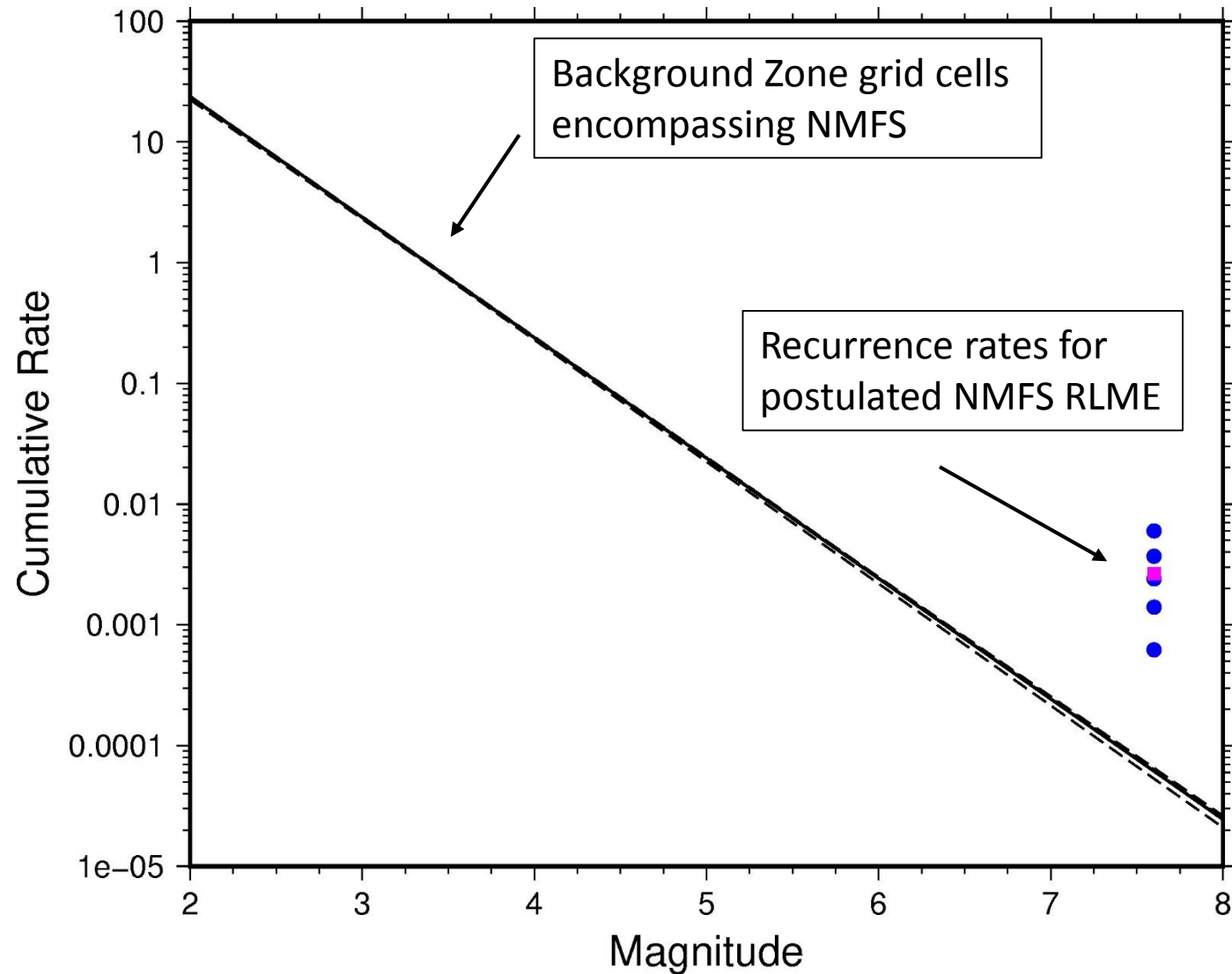**MESE-N, MESE-W, Study-R**

RR

MESE-N

0.25° spacing: 32 grid cells

0.50° spacing: 8 grid cells

Earthquakes ≥ magnitude
2.0 – red, 3.0 – green, 4.0 – blue,
5.0 – orange, 6.0 – purple, 7.0 – black

8

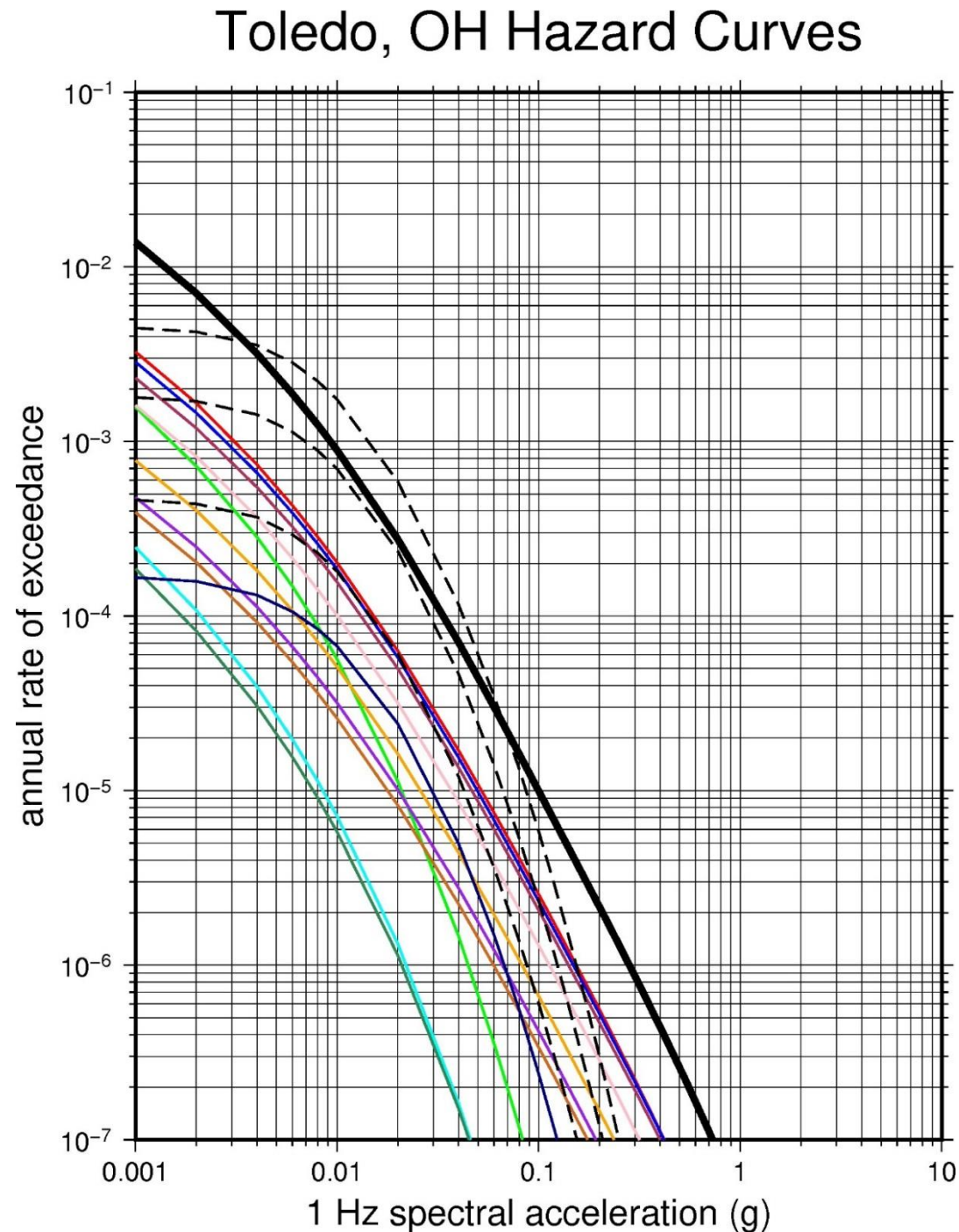# Does Rate from Background Zones Capture Postulated RLME Rates for NMFS?

Background Zone grid cells encompassing NMFS

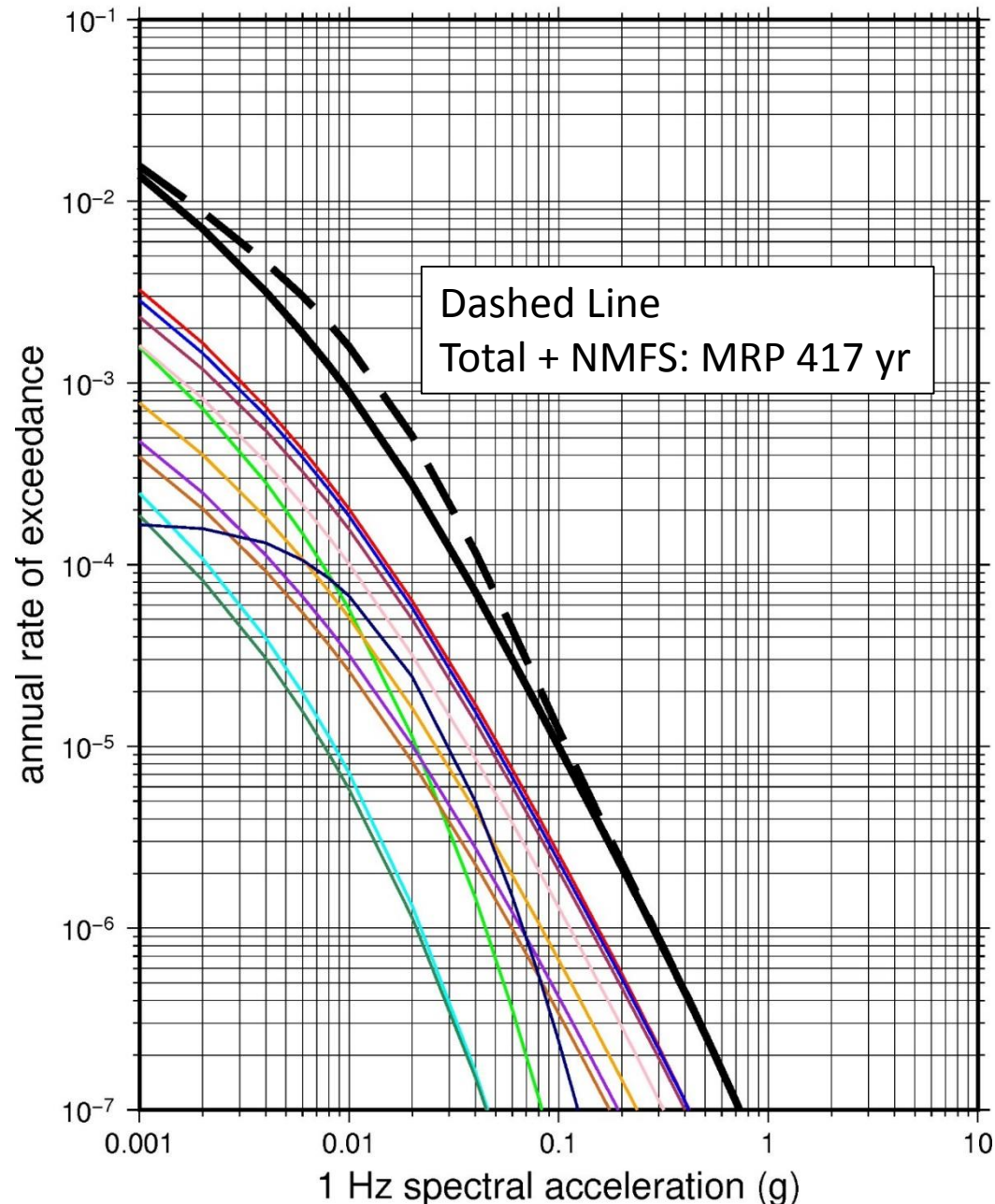Recurrence rates for postulated NMFS RLME

Mean Return Periods (yr):
167
417
1613

CEUS-SSC baseline hazard + Hazard for the NMFS Postulated RLME for varying recurrence rates

Toledo, OH Hazard Curves

annual rate of exceedance vs 1 Hz spectral acceleration (g)

Total
MIDC-A
NMESE-N
STUDY_R
MIDC-B
IBEB
MIDC-C
NMESE-W
MIDC-D
PEZ-N
PEZ-W
Wabash

Dashed Lines NMFS:
Mean Recurrence Period (MRP) (yr)
167
417
1613

Toledo, OH Hazard Curves

Legend:
- Total (black)
- MIDC-A (red)
- NMESE-N (blue)
- STUDY_R (dark red)
- MIDC-B (pink)
- IBEB (green)
- MIDC-C (orange)
- NMESE-W (purple)
- MIDC-D (brown)
- PEZ-N (cyan)
- PEZ-W (teal)
- Wabash (dark blue)

Dashed Line
Total + NMFS: MRP 417 yr

X-axis: 1 Hz spectral acceleration (g)
Y-axis: annual rate of exceedance

Conclusion – Postulated NMFS

- Due to large source-to-site distance adding NMFS RLME (MRP: 417yr) increases the 1 Hz SA by a fairly small amount at Toledo, OH
  - 10^{-4} AEF: 0.03 g to 0.04 g
  - 10^{-5} AEF: 0.08 g to 0.10 g

- Sensitivity study assesses impact of postulated RLME on 1 Hz hazard for site, but study does not evaluate plausibility of postulated RLME

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Background Information – Quail Fault

A multi-institution deployment of seismometers in the epicentral region yielded a well-recorded (>395 events) aftershock sequence for the Mineral earthquake

Aftershock-delineated fault plane – termed the "Quail Fault" (Horton et al., 2015, doi:10.1130/2015.2509(14)):

- N36°E, 50°SE

- Length = ~10 km
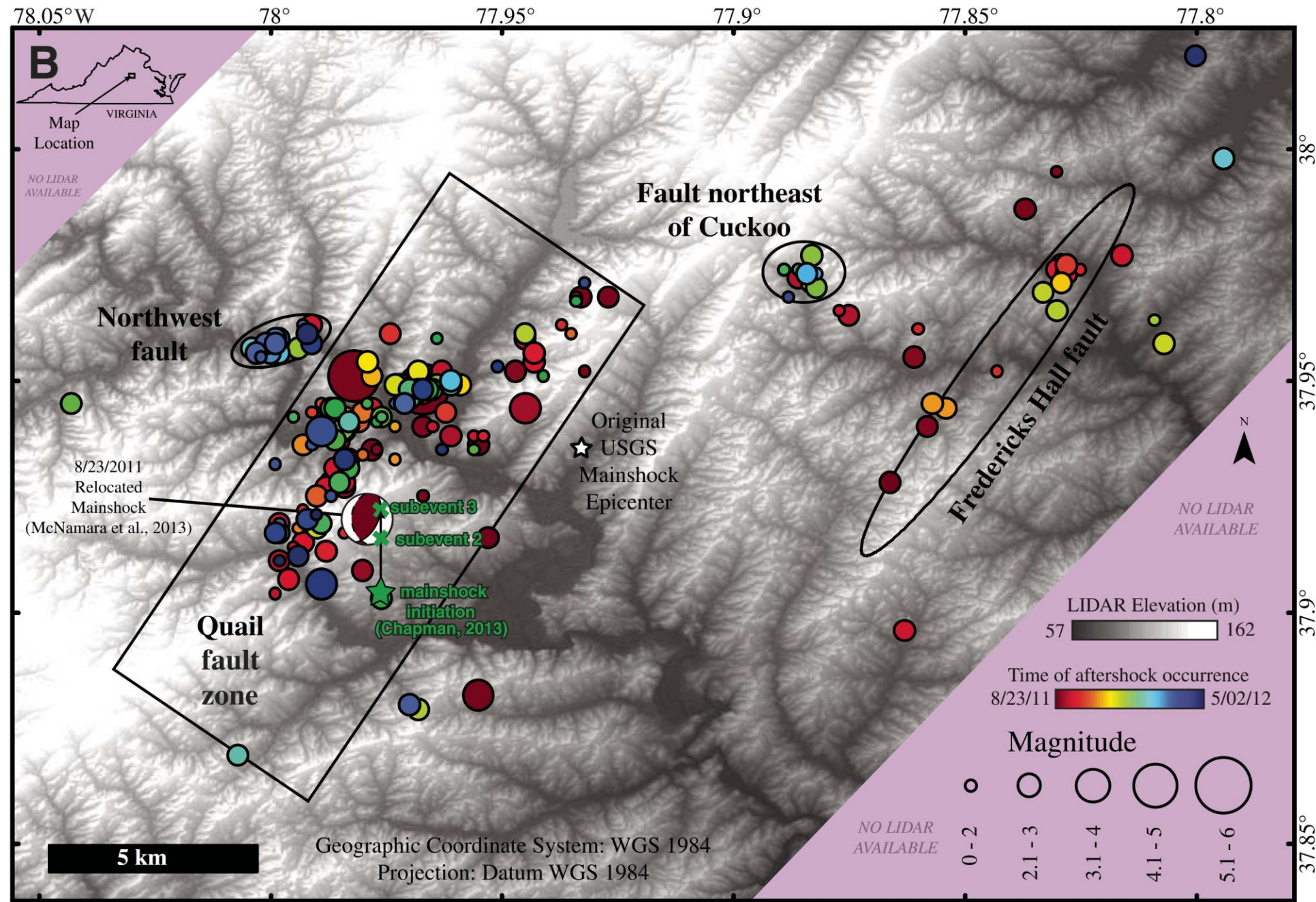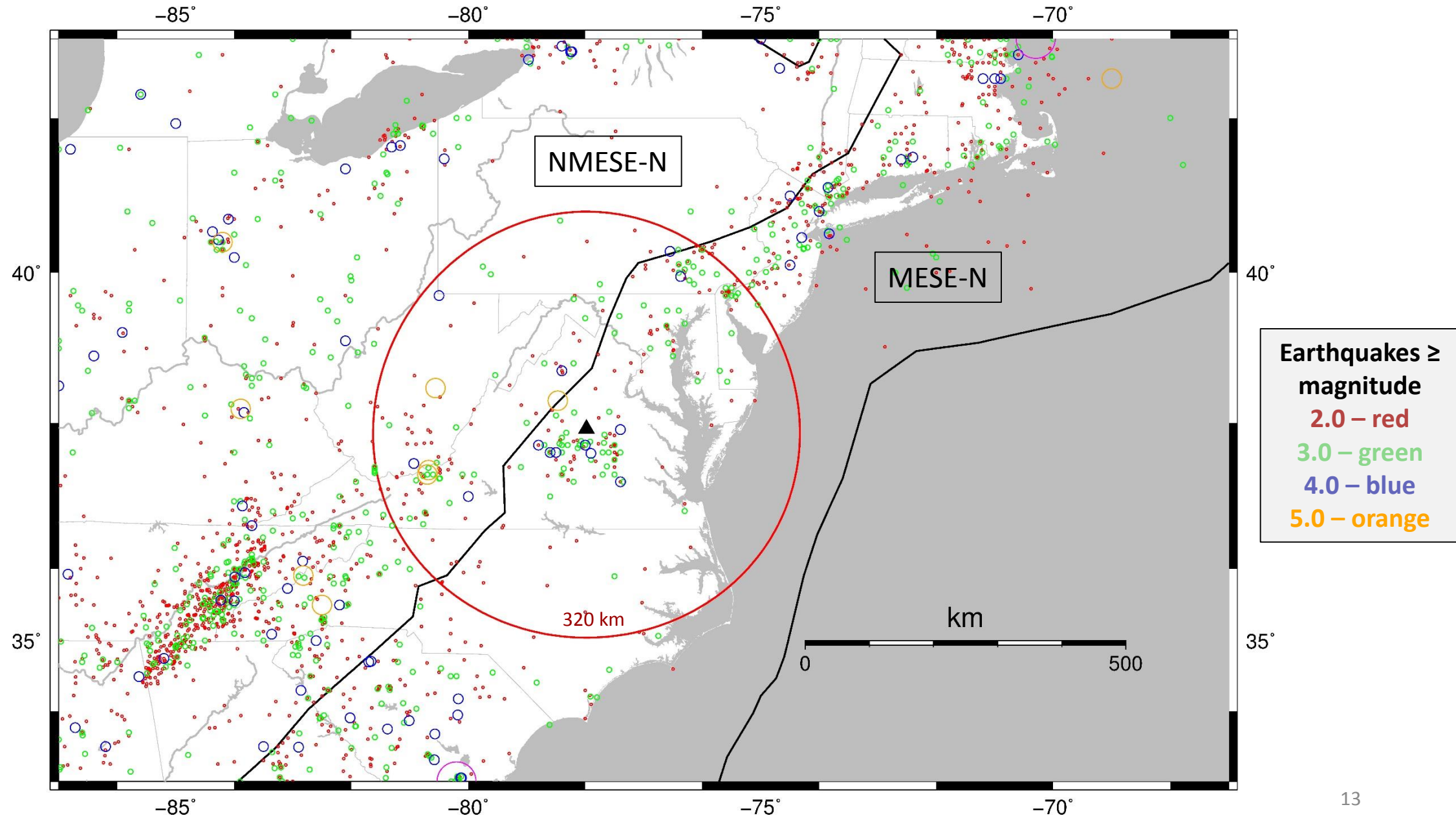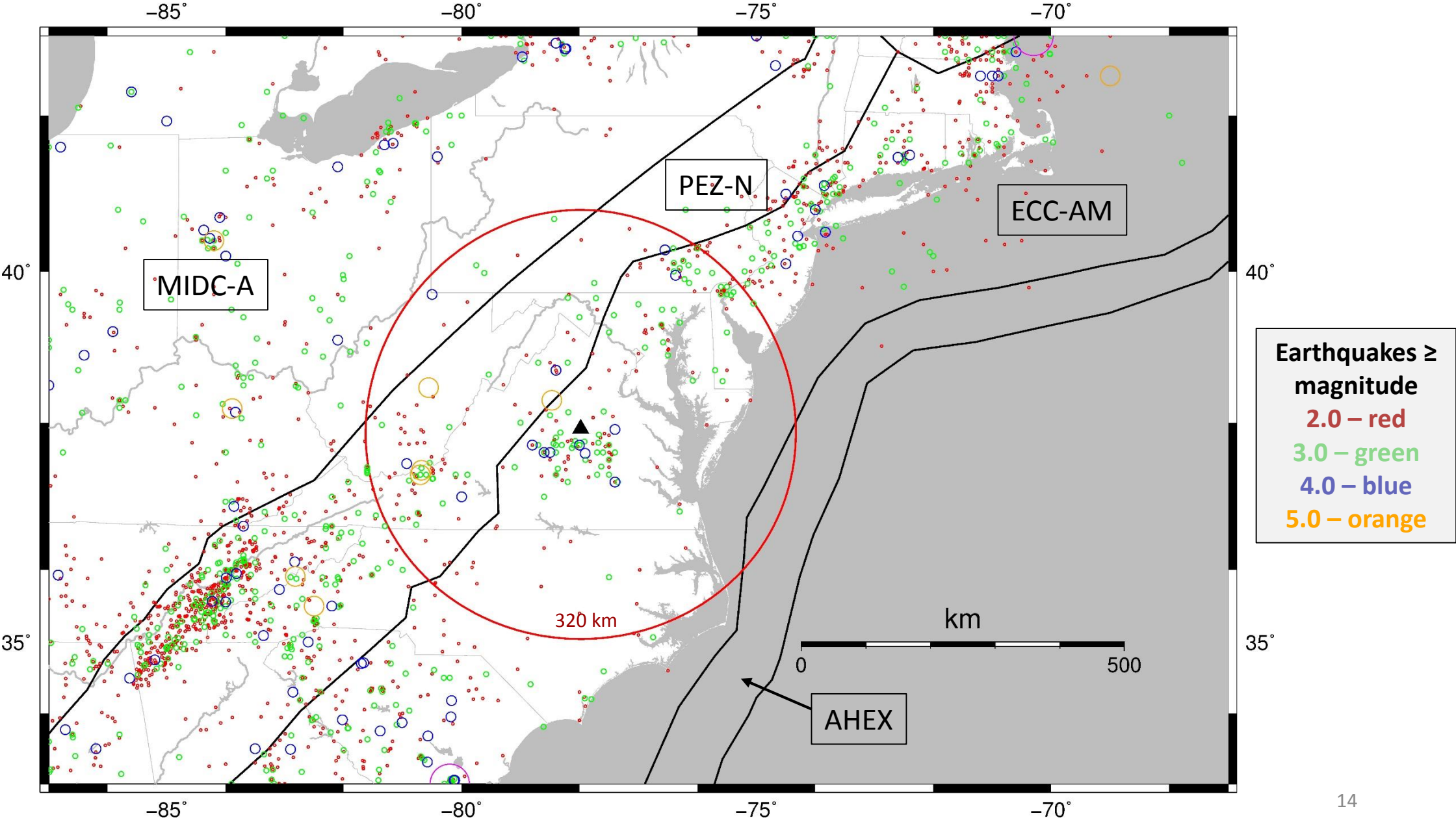
- Width = ~8 km

- Depth = 7 km

Figure 4B from Walsh et al., 2015, doi:10.1130/2015.2509(18)
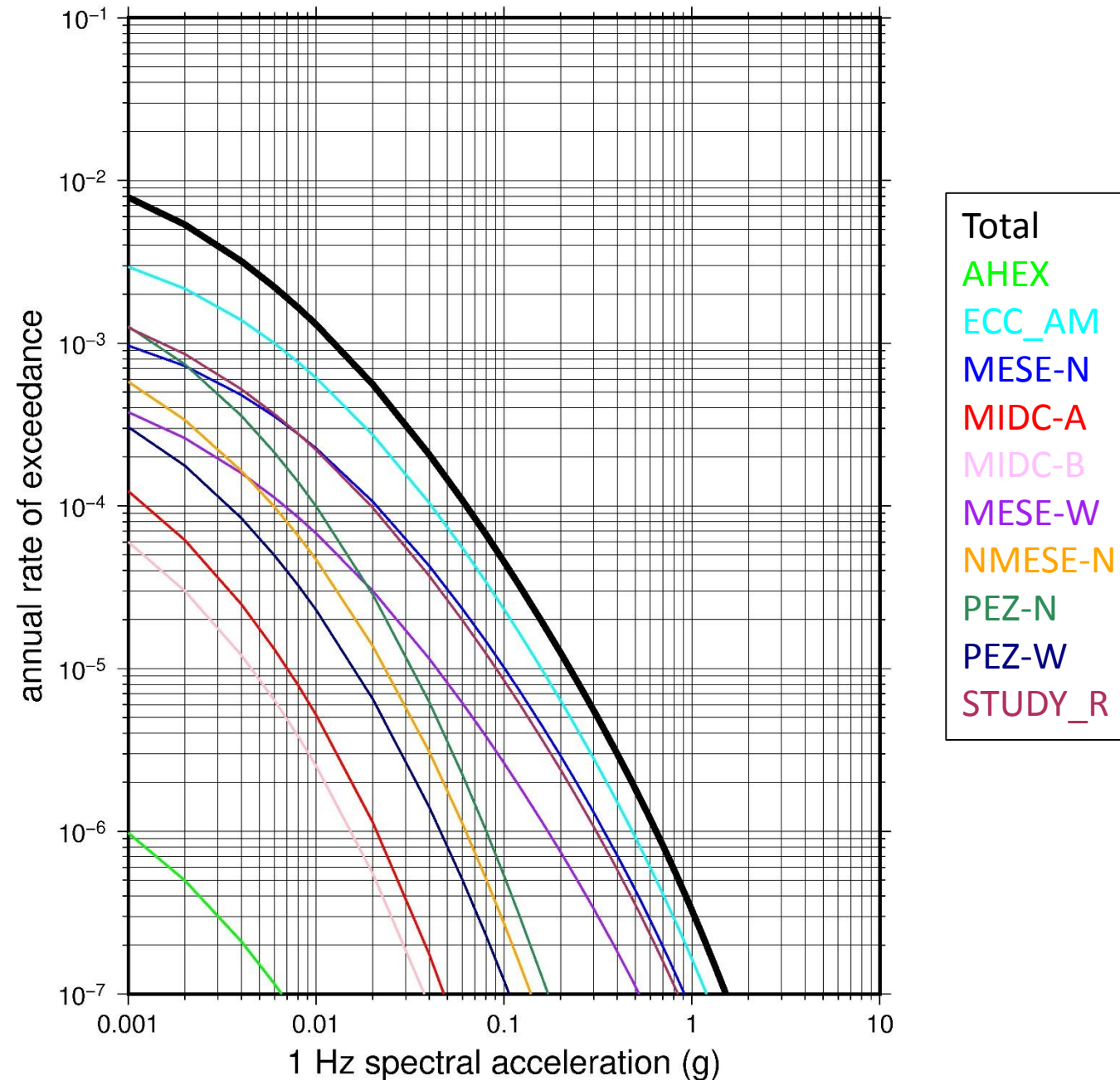
12

Area Sources: Mmax Zones

NMESE-N

MESE-N

320 km

km

Earthquakes ≥ magnitude
2.0 – red
3.0 – green
4.0 – blue
5.0 – orange

0   500

Area Sources: Seismotectonic Zones

PEZ-N

ECC-AM

MIDC-A

AHEX

320 km

Earthquakes ≥ magnitude
2.0 – red
3.0 – green
4.0 – blue
5.0 – orange

km

0   500

CEUS-SSC baseline hazard

Test Site 18:
5 km southeast of epicenter
(hanging wall
of Quail fault)

Site 18 Hazard Curves

annual rate of exceedance

1 Hz spectral acceleration (g)

Total
AHEX
ECC_AM
MESE-N
MIDC-A
MIDC-B
MESE-W
NMESE-N
PEZ-N
PEZ-W
STUDY_R

Quail Postulated Fault Source

Seismotectonic Zones: ECC_AM
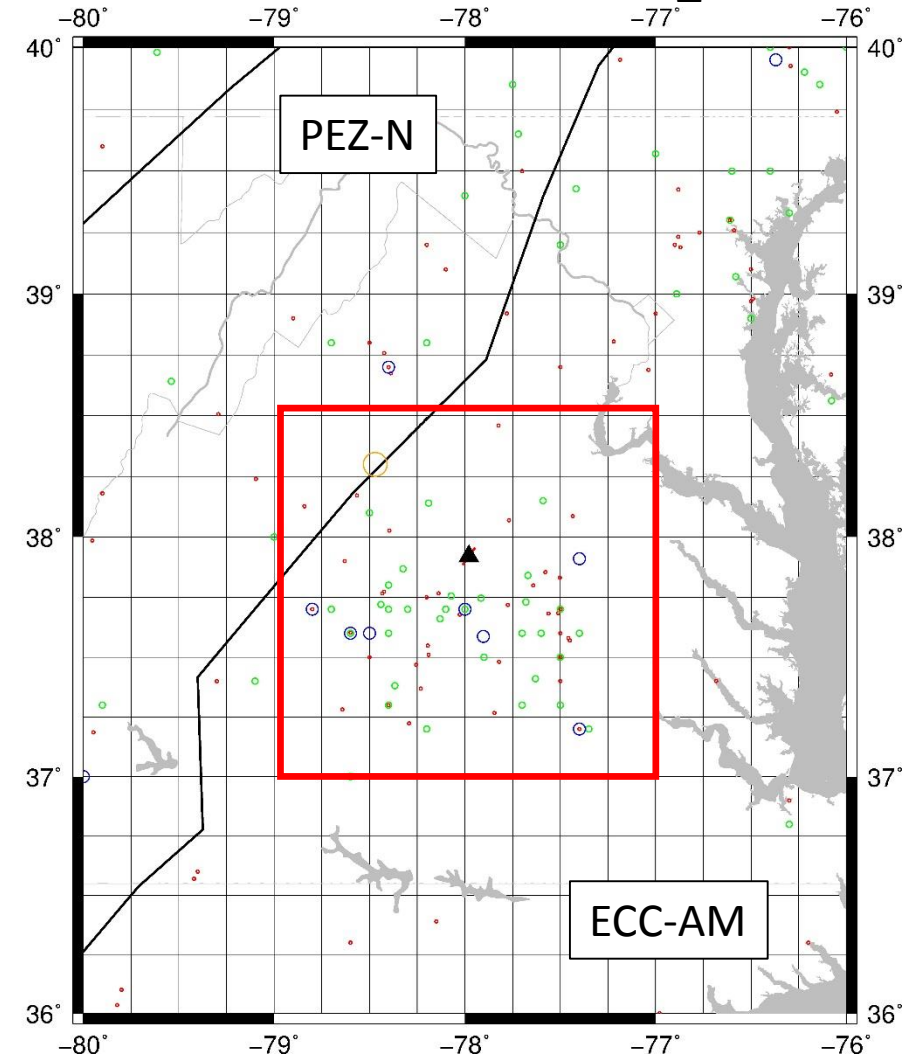
0.25° spacing: 16 grid cells

Mmax Zones: MESE-N, MESE-W, Study-R
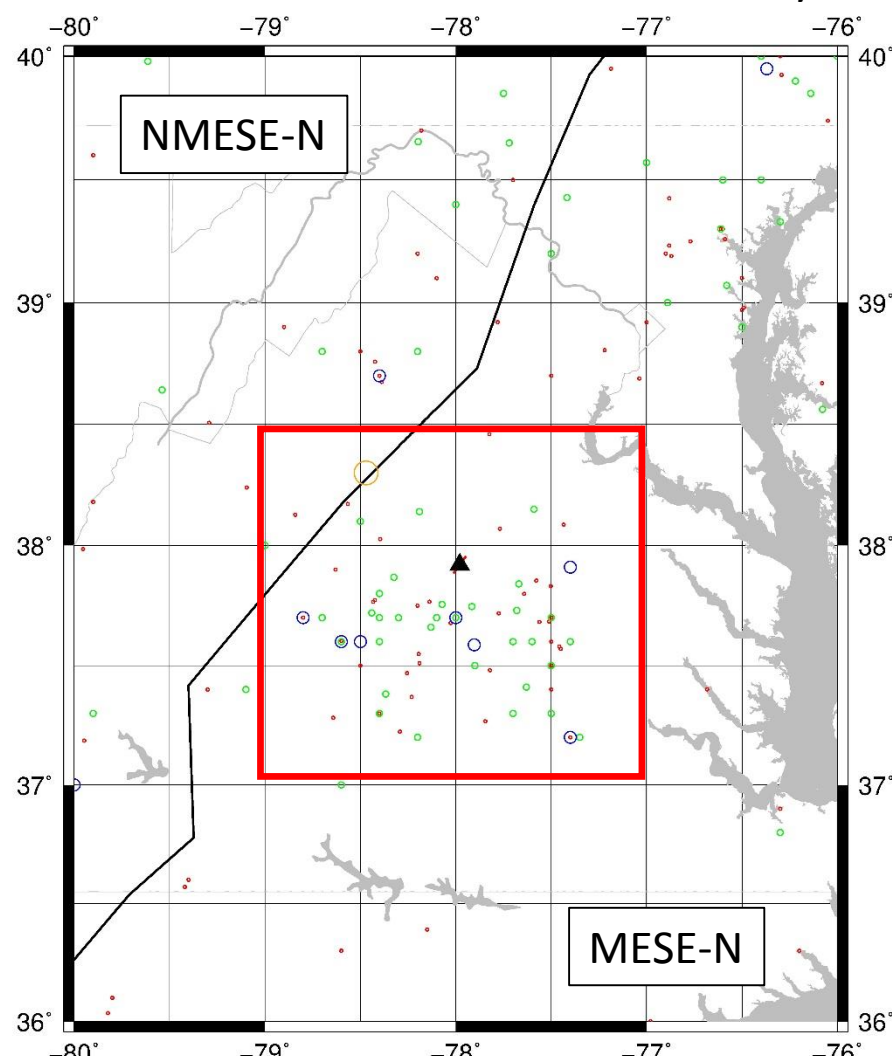
0.50° spacing: 8 grid cells

- Grid spacing is same as NMFS

- Source only resides in 2 grid cells (beneath triangle marking center of fault)

- Expand to capture background seismicity rate in nearby central Virginia seismic zone

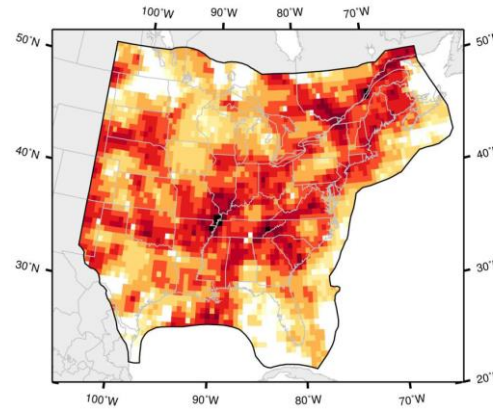**Earthquakes ≥ magnitude**
2.0 – red
3.0 – green
4.0 – blue
5.0 – orange

CEUS-SSC Model includes 24 rates (defined by a and b-values) for each source
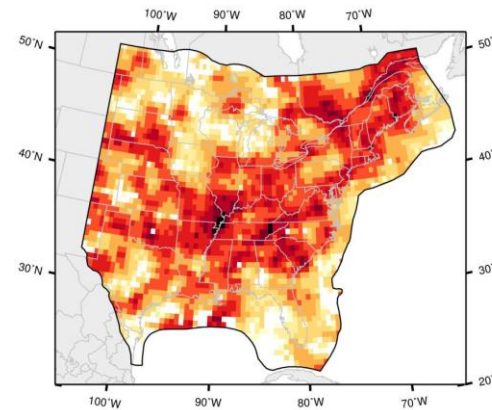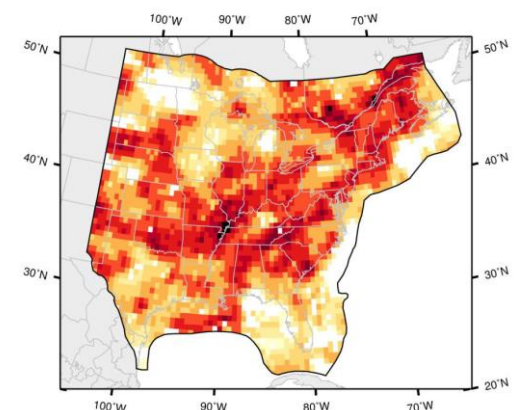## *8 realizations of recurrence maps x 3 cases (case A, B, E)*
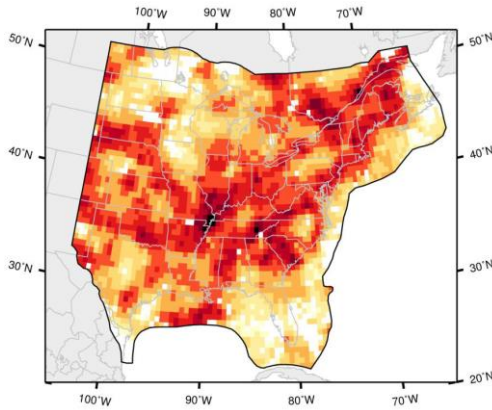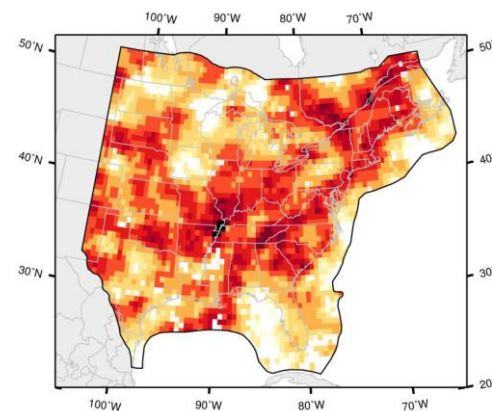

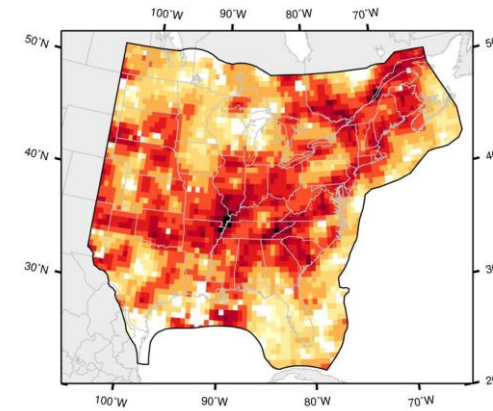
Realization 1 Realization 2 Realization 3 Realization 4

Realization 5 Realization 6 Realization 7 Realization 8

From NUREG-2115 (CEUS-SSC Model) – Appendix J
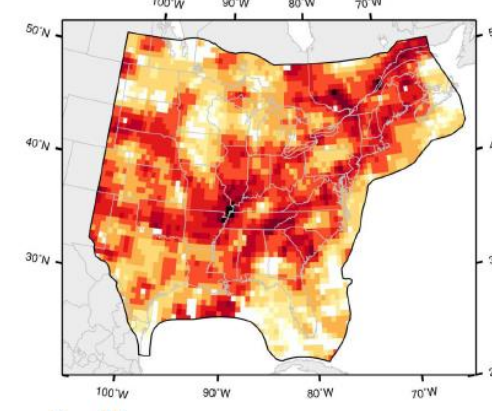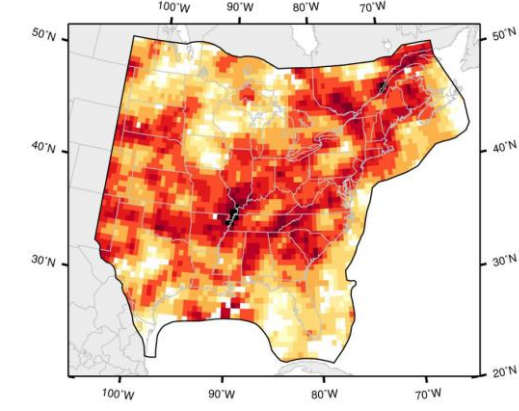
Next Steps – Postulated Quail Fault RLME

- Extract seismicity rates for mmax and seismotectonic grid cells and create magnitude – rate plot for establishing recurrence characterized by background sources

- Run hazard for the Quail Postulated Fault Source using *faultsource_31* program together with EPRI (2013) GMMs for a range of recurrence rates (0.01, 0.1, 1, and 10 mm/yr)

- Compare the hazard at site with and without adding the postulated fault source at 10^{-4} and 10^{-5} annual frequencies of exceedance for 25 test sites (0, 5, 25, 50 km from postulated fault)

- Make final evaluation as to whether including the Quail Postulated Fault Source in CEUS-SSC significantly impacts the hazard at the test sites

Preliminary Conclusions

- This sensitivity study provides a traceable approach for quantifying and visualizing the potential significance of an aftershock-delineated rupture plane on an existing PSHA in central Virginia

- Geologic and seismic field evidence of recurrence seismicity of the Quail Fault would need to be established before including the aftershock-delineated rupture plane as a discrete seismic source in the CEUS-SSC model